THE EFFECT OF UNTIMELY LOSS OF DECIDUOUS MOLARS ON THE DEVELOPMENT AND ERUPTION OF THE PREMOLARS

By

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Submitted to the Faculty of the Graduate School of Indiana University School of Dentistry in partial fulfillment of the requirements for the degree of Master of Science in Dentistry,

1964.

ACKNOWLEDGEMENTS

The author wishes to acknowledge Dr. Ralph E. McDonald for his guidance and patience in the preparation of this thesis and, moreover, for his direction of the author's graduate program.

Further acknowledgement is directed to Dr. Charles J. Burstone for his advice in the cephalometric aspects of this study and for his interest in this project.

The author wishes to thank Dr. Phillip E. O'Shaughnessy for his assistance in testing certain radiological aspects of the method employed in this study and to Dr. James O. Beck for his aid and advice in this area. Appreciation is also directed to Miss Dessie Auter and Mrs. Isabel Poor of the department of radiology for their aid in the preparation of the films used in this study.

Gratitude is extended to Dr. Stanley C. Herman for his introduction to the author of the 45 degree cephalometric technique and for his assistance in evaluating a portion of the data included in this study.

The author wishes to thank Mrs. Lillian Deisroth for her chairside assistance during the clinical procedures included in the study.

The author wishes to thank Mr. Richard Scott for his advice and assistance in the preparation of the tables and illustrations included in this thesis.

The author wishes to thank Mrs. Sara Snyder for her advice and criticism in the writing of this thesis.

The author desires to express special gratitude to his wife, Arden, for her understanding and many sacrifices during the author's graduate study.

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INTRODUCTION

In offering dental care for children, the author has been confronted numerous times with the problem of planning treatment for the child who has experienced the extraction of a deciduous molar at an age earlier than its anticipated shedding date. While the experience of others and reports of research in the literature have convinced the author that provision of space maintenance to prevent loss of space in the dental arch is usually advisable, the problem is somewhat more complex.

What type of space maintainer should be employed? The design of this type of appliance can be influenced by a number of considerations, one of which is the length of time that the child will be required to wear the appliance. This is dependent on the date that the successor to the extracted tooth will clinically emerge. In order to predict this event, it is necessary to know what effect the extraction may have on the development and eruption of the successor tooth.

The author has found the literature to be of little value in answering the latter question, in terms of the individual child. Several authors have proposed that the effect of the extraction of deciduous molars shows individual variation and is dependent on such variables as the age of the patient, the presence or absence of infection and the loss of alveolar bone. However, these statements have been supported only by random observations in most instances. There have been a number of studies related to the effect of deciduous molar loss in large populations, but only one concerned with individual variation.

There is a second aspect to be considered in the relationship of deciduous molar extraction, premolar emergence and space maintainer design. The importance of the sequence of eruption of the permanent teeth in the development of a desirable permanent dentition has been generally accepted. It has been stated that when the untimely loss of a primary molar occurs, the type of space maintainer provided, functional or non-functional, can in itself influence the eruption of the successor tooth. If this is true, it would suggest that the dentist might favorably influence the sequence of eruption by the design of the appliance provided. There has been no research to substantiate or deny that such a relationship exists.

It would seem that considerable research is needed to provide information concerning the effect of untimely loss of deciduous molars on the eruption of premolars in respect to the possible variables involved. The realization that a lack of information exists in this area prompted the author to undertake this serial, radiographic investigation which, while admittedly of short duration, will perhaps add something to this void in knowledge.

REVIEW OF LITERATURE

Prior to 1951, there were no reports of organized research directed toward the effect of premature loss of deciduous molars on the timing of either the development or eruption of the permanent successor teeth. However, the possibility of such an effect was suggested at least as early as 1923 when Hellman[1] stated, "...no observing orthodontist has failed to experience certain difficulties in treatment arising by the premature loss or too long retention of some deciduous teeth. To him also the tardy eruption of some of the permanent teeth is often a source of annoyance."

The early studies concerned with the effect of early loss of deciduous teeth on the development of the permanent dentition were directed toward the spatial rather than temporal changes that might result. Ungar,[2] Cohen,[3] Brauer,[4] Schachter,[5] Breakspear,[6] Rosenzweig and Klein[7] reported on the incidence of premature loss of deciduous teeth and dimensional changes in the dental arches. Schachter,[5] however, observed that the extraction of a "septic" deciduous tooth was not infrequently followed by the premature eruption of the succeeding premolar and that the deciduous tooth with a "live" pulp, if extracted too early, led to the delayed eruption of the premolar.

Advocates of the "serial extraction procedure," in the mixed dentition as a preventive orthodontic measure, have based their therapy in part on the effect early extraction of deciduous molars and cuspids may have on the time of emergence of the successor teeth. Hotz[8] claimed that the premature extraction of deciduous first molars will provoke early eruption of the first premolars. Kjellgren,[9] Grossmann[10] and Dewell[11] made similar statements without documentation in papers explaining the rationale of this procedure.

Moreover, statements regarding the effect of early loss of primary teeth on the eruption of permanent successors have been made by authors in a variety of textbooks, also without reference to documented evidence. Boyle[12] states, "Premature eruption of the permanent teeth occurs, especially in the bicuspid region, because of the early extraction of the deciduous teeth." Thoma[13] and Stones[14] also associated early eruption of primary teeth and the early extraction of their deciduous predecessors. Moyers[15] comments, "The premature loss of any primary tooth means the earlier arrival of its permanent successor."

Leslie was the first to report investigating the effect of premature loss of deciduous teeth on the time of eruption of the permanent successor teeth. He examined 248 girls and 255 boys, all New Zealand schoolchildren, ages 10 to 11 years, and grouped them by sex and by positive or negative deciduous molar extraction experience. After comparing the mean eruption ages of the premolar teeth for each group, he concluded that the "overall" effect of premature extraction of deciduous molars is to expedite the eruption of the permanent successors. He suggested, however, that there may be variation in this effect as related to individuals.

Kronfeld[17] reported a serial study of 400 children, each examined periodically at New York University from an age prior to four years until the early years of the complete dentition. Radiographic surveys, made every six months, and study casts, made annually, were utilized.

He compared the mean eruption ages of 203 maxillary and mandibular first and second premolars whose deciduous predecessors had been extracted to the comparable ages of 495 premolars whose predecessors had been shed normally. He offered two conclusions concerning the effect of premature loss of deciduous teeth on the eruption time of the permanent successors. Very early loss, he stated, results in delayed eruption while premature loss within one to one and one-half years of the normal shedding time results in hastening of the eruption of the permanent tooth.

Clements, Davies-Thomas and Pickett[18] found the mean age of clinical emergence of permanent teeth in British schoolchildren in 1948 to be earlier for all teeth except premolars when compared to the mean eruption age standards of 40 years previous. Eruption of the premolars, they suggested, was attributable to fewer extractions of deciduous molars in the more recent population which, if true, would suggest that the untimely loss of deciduous molars has the effect of accelerating the clinical emergence age of the premolars.

In the report of a cross-section study of eruption in 16,000 Czechoslovakian children, ages nine to 16 years, Ponkova and Hajek[19] concluded, that the premature loss of deciduous teeth did not influence greatly the development and eruption of the permanent teeth.

Fanning[20] reported a serial radiographic study of four boys and four girls at Harvard University who had experienced unilateral extraction of one deciduous molar. Using the antimere as a control in each subject, she followed the eruptive movement and rate of development of the contralateral succedaneous teeth at six-month intervals until one or both had clinically emerged. The extractions occurred at ages varying from four to nine years. In four of the children there was periapical pathology associated with the extracted deciduous molar. She reported that premature loss of a deciduous molar in no case affected the rate of formation of the permanent successor. She found, however, that in every case the successor to the lost deciduous tooth experienced a marked "spurt" in its eruption rate when compared to its antimere. Following this intitial spurt, she reported that the rates of eruption differed among individuals so that the time of clinical emergence of the permanent teeth also varied.

Butler,[21] in a survey of eruption ages of 1,943 British schoolchildren, selected 976 cases for which records of past dental treatment were available. In those cases in which premature extraction of deciduous molars had occurred the specific tooth involved and the child's age at removal were recorded. Also, the absence or presence of the corresponding successor tooth and the child's present age were noted. Following a statistical evaluation of these data, Butler[21] concluded, that early eruption of premolar teeth is not apparently associated with the early loss of deciduous teeth but is more probably due to "a general association with growth and development."

As part of a more extensive survey, Adler[22] recorded the decayed, extracted and filled deciduous molar experience in 13,205 Hungarian children, ages six and one-half to eight and one-half years. He grouped the children into two samples, those with high caries experience and those with low experience. After comparing the mean eruption ages of the premolars of the two groups, he concluded that premature extraction of a deciduous molar, an event he related directly to caries prevalence, was associated with an accelerated eruption of the permanent successor.

Carr[23] studied the eruption of the permanent premolars in 3,681 individual dental quadrants of an unspecified number of Australian boys and girls, ages nine to 11 years. He classified each quadrant into one of three groups: group 1 comprised those quadrants in which deciduous molars had exfoliated naturally or had been extracted after the age of 10 years; group 2, those quadrants in which deciduous molars had been extracted before the age of seven years; and group 3, those in which deciduous molars had been extracted between the ages of seven and 10 years. He recorded the ages of eruption of the permanent premolars in each group and compared them with normal values of mean eruption ages of Australian children.

Carr[23] made the general conclusion that the age of eruption of the permanent premolars is greatly affected by the extraction of the deciduous molar teeth. Extraction of the deciduous molars in the mandible before the age of seven years, he stated, caused a delay in the eruption of the mandibular premolars which he attributed to a loss in arch length. On the other hand, he concluded that extraction of deciduous molar after the age of seven in either jaw caused an acceleration of the eruption of the permanent premolars.

Sleichter[24] reported a study at Iowa University of 39 children who had premature extraction of deciduous teeth. The state of eruption of the premolar underlying the extracted tooth was assessed in each case by means of a llinear measurement from the tip of the crown to the crest of the alveolar bone on a periapical radiograph. This measurement was compared to an identical measurement of the antimere which served as a control. Sleichter,[24] concluded that premolar eruption is hastened by early, but not too early, extraction of deciduous molars.

STATEMENT OF THE PROBLEM

The purpose of this study was to serially investigate the initial effects that the extraction of a deciduous molar, prior to its anticipated shedding date, may have on the rate of eruption and the rate of development of its succedaneous premolar. Furthermore, the study was designed to study these effects in the absence of certain variables that are often associated with the untimely loss of a deciduous molar and which, themselves, have been thought to influence the eruption of the succedaneous tooth.

EXPERIMENTAL PROCEDURE

Eight children, four boys and four girls, ranging in age from six years and two months to 11 years and eight months, patients of the Pedodontic Clinic of the Indiana University School of Dentistry, were selected to participate in this study (Table I). Each child was in the mixed dentition stage of dental development with all eight deciduous molars present. Each exhibited a clinically normal occlusion and offered an unremarkable medical history. Recent study models and full-mouth radiographic surveys were available for each subject. None presented clinical or radiographic evidence of pulpal pathology associated with any tooth.

Selection was further based on the need for the untimely loss by extraction of one mandibular deciduous molar when successful restoration of the tooth was doubtful due to the extent of a carious lesion and the accompanying loss of tooth structure. Each child received all other necessary dental treatment during the duration of this study.

Prior to the extraction of the selected deciduous molar, a soldered, mandibular lingual arch space maintainer was fabricated for each child, utilizing Johnson gold bands and .045 gold wire. The mandibular first permanent molars served as abutments. The arch wire was positioned so that no contact was made with either tooth structure or alveolar ridge tissue in the buccal segment areas. The space maintainer was cemented at the same appointment at which the extraction was managed.

Extraction of the selected deciduous molar was accomplished with simple forceps technique and mandibular block anesthesia. In no case was there surgical removal of bone nor instrumental curretage of the socket. All extractions were managed without operative or post-operative complications.

Immediately following the extraction procedure, left and right 45-degree cephalometric films were made for each child. The major equipment utilized in this technique consisted of a Westinghouse x-ray machine (Model No. 978709D), operating at a peak of 90 kilovolts and 12 milliamperes, and a Wehmer adjustable cephalostat. The target-film distance was kept constant at 60 inches. All exposures were made at 0.4 seconds on Kodak Blue Brand Medical film in standard 8 x 10 cassettes with intensifying screens.

The head-holder portion of the cephalostat was rotated so that the mid-saggital plane of the patient, when positioned, was 45 degrees to the central ray with the patient's side of interest furthest from the x-ray tube (Figure 1). Each child was positioned in the head-holder with the Frankfort Horizontal plane parallel to the floor and with the teeth in centric occlusion.

Subsequent left and right 45 degree cephalometric films were made for each child after three months and again at six months for six of the subjects.

The various determinations included in this study were made from the collected series of films for each child. The succedaneous premolar to the extracted deciduous tooth was designated as the study-tooth. The antimere of this tooth served as the control. Determinations were also made for the other two mandibular premolars for each subject. In recording data, the Palmer notation was used to designate specific teeth and each subject was assigned a number (Table I).

Tracings of both the initial left and right films for each subject were made on acetate paper with a sharp, 4H pencil, reproducing as carefully as possible the bony and dental images of the mandible. The most coronal calcified point was located for each premolar, designated as the cusp-tip, and marked on the film and tracing with a pin-hole. The cusp-tip points for all premolars were similarly located and marked on the subsequent films.

The initial tracing of each side of each subject was placed over the corresponding three-month film and oriented in the following manner: Bony images of the mandibular inferior border beneath the premolars reproduced on the tracing were superpositioned on the corresponding bony images of the three-month film. A measurement was made between the two cusp-tip pin-holes for each premolar with a sliding vernier caliper to 0.1 millimeters. The same procedure was done with the initial tracing and the six-month film for six of the subjects. The distance between successive cusp-tip pin-holes was considered as the eruptive movement of the premolar. The values were recorded for each study tooth and control tooth and the difference in each interval was assessed (Table II). The values for the other mandibular premolars for each subject were also recorded (Table III).

Composite tracings of the initial, three-month, and six-month films were made for each subject by superpositioning the bony images of the inferior border of the mandible. The cusp-tip of each premolar and cuspid was located and marked with a sharp, 4H pencil. Two points were located along the inferior border of the mandible on each composite tracing by selecting a point for each that most closely represented a landmark chosen for that point. The landmarks chosen and their corresponding points (Figure 3) are as follows: (1) The most inferior point on the anterior aspect of the inferior border of the mandible, designated as point AI, and (2) the point of greatest concavity of the antegonial notch, designated as point AG. A base line was constructed on the composite tracing between these two points. The composite tracing for each side for each subject was positioned on a sheet of ruled graph paper with coordinates of two millimeters. The tracing was oriented to the graph paper for measurement of each tooth with the constructed base line corresponding to a horizontal coordinate and the point representing the initial cusp-tip falling on a vertical coordinate. The amount of anteroposterior change between the initial cusp-tip and successive cusp-tips for each tooth was determined by measurement along the closest horizontal coordinate with a vernier caliper to 0.5 millimeters.

The distance between the initial cusp-tip and that at six months was designated as the antero-posterior component of eruptive movement and recorded for six subjects (Table VI).

Two methods were employed to determine the rate of development of the premolars. The first method consisted of successive linear measurements of the developing root; the second method, a quantitive determination of the stage of development of each tooth image by comparison with a prepared illustration of arbitrary stages of development for premolar teeth.

In the first method, the most inferior calcified image of the developing root was located for each premolar on each film and marked with a pin-hole. A perpendicular was established from this point to the apparent long-axis of the tooth. A measurement was made with a sliding vernier caliper between the point of intersect of these two lines and the cusp-tip pin-hole. The distance between these two points was considered as the tooth length. The difference in measurements for the same tooth on any two successive films was considered to be the increase in root length; and the increase in root length for any given interval, the rate of development.

These values were recorded for each study tooth and control tooth and the difference in each interval was assessed (Table V). The values for the other mandibular premolars for each subject were also recorded (Table VI).

For the second determination of development, an individual tracing of each premolar image on each film was made. The tracings for each subject were then transfered to a sheet of white drawing paper, arranged in an orderly fashion in rows and columns. Each traced image was matched with a diagramatic representation of a developing premolar. These representations were prepared by Moorrees, Fanning and Hunt[25] to portray arbitrary stages of development of single-rooted teeth and were arranged in order in a prepared illustration with code letters assigned to each stage (Figure 4). Score sheets were prepared for each subject with boxes arranged to correspond with the arrangement of traced premolar images. The code letters indicating the stage of development that matched the traced image was recorded in the appropriate box on the score sheet. This procedure of evaluation, i. e., the matching and recording, was done twice, independently by the author and one other investigator (S. H.). Their results were compared to provide a "double determination" in this evaluation.

RESULTS

The eruptive movement of premolars included in this study varied during both three-month intervals (Tables II and III). In two cases (Patients No. 3 and 4) no observable change between cusp-tip pin-holes was found during a three-month interval. The greatest amount of eruptive movement for a three-month interval was observed in Patient No. 1, whose right first premolar showed 4.2 millimeters of movement during the first three-month period. The mean amount of eruptive movement for all premolars during a three-month interval was 1.2 millimeters.

All eight study teeth exhibited some amount of eruptive movement during both three-month intervals. The least amount of movement occurred twice in Patient No. 3, whose study tooth moved 0.6 millimeters during each of the two three-month periods. The greatest amount of movement for a study tooth occurred twice in Patients No. 2 and 3 with 3.6 millimeters of change, observed for both in the first interval following extraction. The mean amount of eruptive movement for the study teeth for a three-month interval was 1.98 millimeters. In the six patients followed through two three-month intervals, a comparison of the eruptive movement of study teeth in the first three-month interval to that in the second interval revealed more movement during the first period for three teeth, less for two teeth and the same amount for one tooth.

The eruptive movement of the eight study teeth when compared to that of their antimeres during the first three-month interval was found to be greater in every instance (Table III). The largest difference was 2.9 millimeters (Patient No. 1) and the smallest, 0.1 millimeters (Patients No. 2 and 3). During the second three-month interval, three of the six study teeth showed greater movement with the greatest difference being 2.8 millimeters (Patient No. 1). In three cases, the study tooth and its antimere moved the same amount. In no instance did the control tooth demonstrate greater eruptive movement than the study tooth.

The mean amount of eruption for all premolars other than the study teeth for any three-month interval was 1.19 millimeters. When compared to the mean value for the study teeth (1.98 millimeters) by means of a t-test, $t = 3.09$ and $0.001 < P < 0.01$.

The assessment of an antero-posterior component of eruptive movement during a three-month interval was not found to be significant in a majority of cases due to the small increments of distance involved. Therefore, only the results for the six teeth studied for six months were considered. Of the 24 premolars observed, 14 showed antero-posterior as well as an occlusual component to the eruptive movement. In all 14 cases, this movement was posterior. Of the 14 teeth, 10 were first premolars. Five of the six study teeth exhibited this component. In two cases (Patients No. 5 and 6), this component was as much as 3.0 millimeters.

The increase in root length for premolars in a three-month period varied from no increase, in five instances, to as much as 3.1 millimeters for Patient No. 6 (Tables V and VI). The mean increase in root length for premolars for a three-month period was 0.83 millimeters.

The range in root length increase for the eight study teeth for a three-month interval was from 0.1 millimeters (Patients No. 3 and 8) to 2.2 millimeters (Patient No. 6). The mean increase in root length for study teeth for three months was 0.95 millimeters. In the six patients followed through two three-month intervals, three exhibited more increase in the study tooth's root length in the first interval and three exhibited a greater increase during the second period.

The increase in root length of a study tooth when compared to their antimeres during the first three-month interval was greater in four cases and less in the other four cases. During the second three-month period, four of the study teeth showed greater root length increase and two exhibited less. In two cases (Patients No. 1 and 2) in which the study tooth's root length had increased comparatively less than the antimere's during the first three-month period, the opposite relationship was noted during the second interval. In two cases (Patients No. 4 and 5) in which the study tooth's root length was more than the antimere's during the first interval, the opposite relationship was noted during the second period.

A comparison of the amount of eruptive movement and the increase in root length for any premolar during a three-month interval shows considerable variation (Tables II, III, V and VI). A total of 56 comparisons were made. In 39 instances the eruptive movement was greater than the concurrent root growth and by as much as 3.3 millimeters. In 16 instances the root growth was greater than the eruptive movement and by as much as 0.9 millimeters. In only one case was the amount of root growth and the eruptive movement identical. A correlation calculated for these two variables found $r = 0.66$.

Of the 88 determinations of the stage of development of traced premolar images made by each of two investigators, there was disagreement in only four instances. Of the 32 premolars investigated, according to the author's determinations, seven showed a change of one stage during the duration of the study. One of the seven was a study tooth. In one instance, there was a change of two stages of development during a three-month period. The study tooth of Patient No. 1 changed from the R 1/4 stage (Figure 4.) to the R 3/4 stage during the second three-month interval. There was no apparent change in the stages of development for the remaining 24 teeth of which six were study teeth, during the periods of observation.

FIGURES AND TABLES

Figure 1. Illustration of patient and apparatus position for left 45 degree cephalometric radiograph.

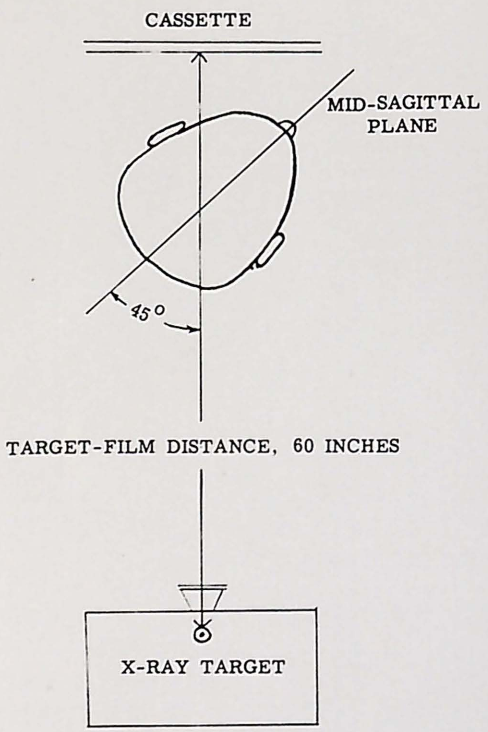
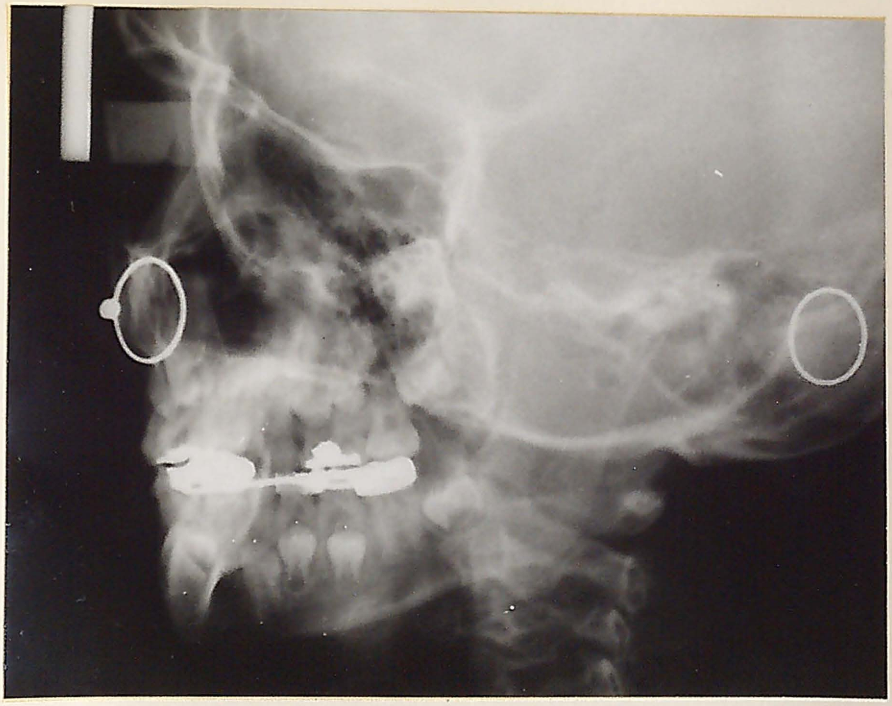
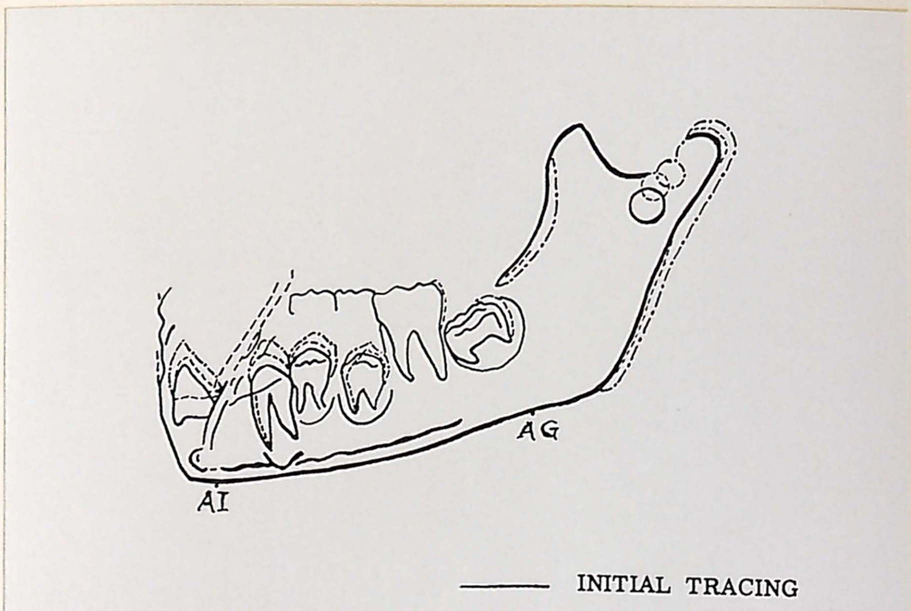


Figure 1. Illustration of patient and apparatus position for left 45 degree cephalometric projection

Figure 2. Initial right 45 degree cephalometric film for Patient No. 4.

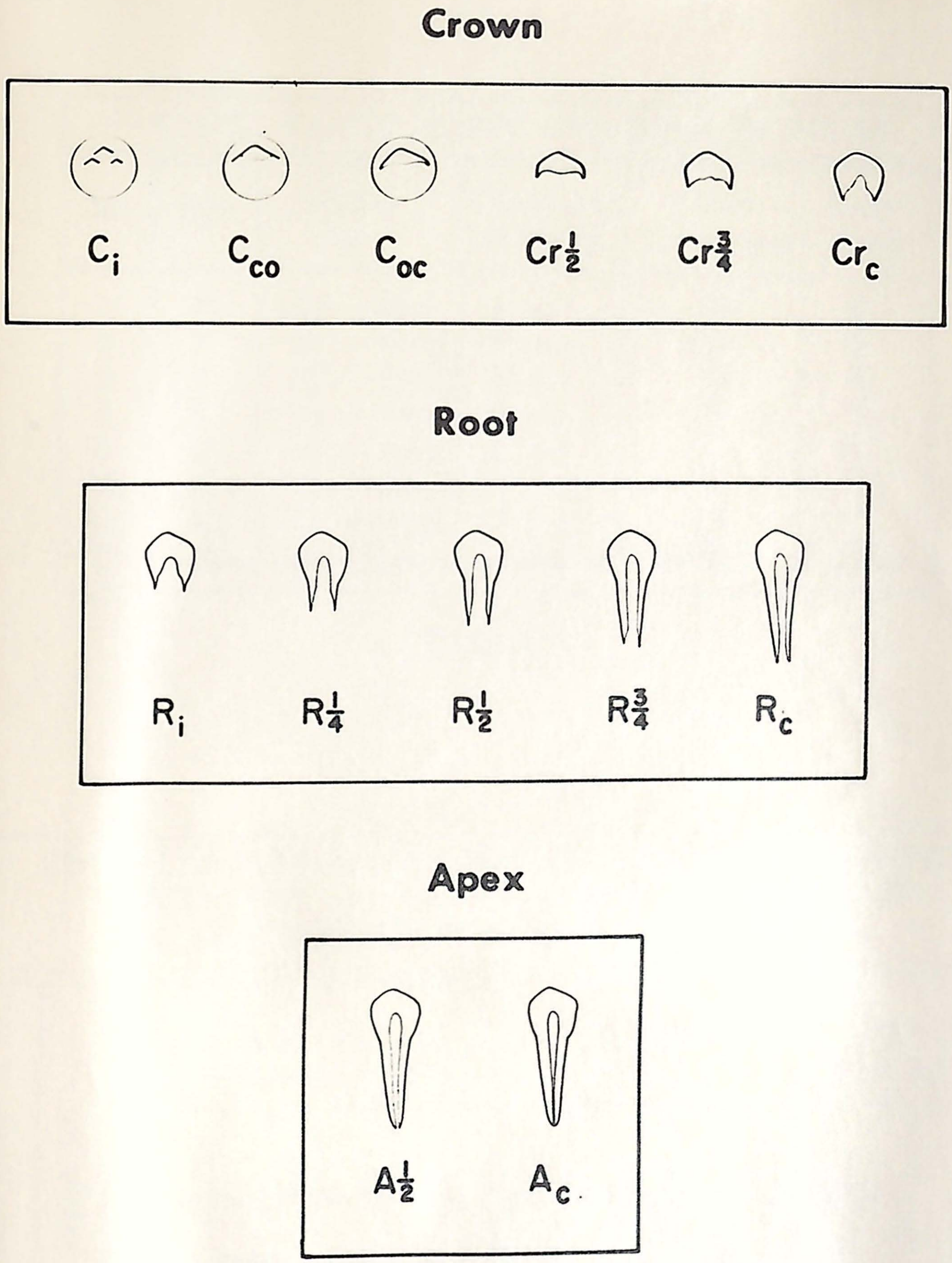
Figure 3. Diagram of composite tracing of initial, 3-month and 6-month films (right) of Patient No. 4. Points AI and AG are shown.





AG
AI
INITIAL TRACING
3 MONTH TRACING
6 MONTH TRACING

Figure 4. Prepared illustration used for assessing stage of development of premolars.



Stages of tooth formation for assessing the development of single-rooted teeth

TOOTH-FORMATION STAGES AND
THEIR CODED SYMBOLS

Stage	Coded Symbol
Initial cusp formation.........	C_i
Coalescence of cusps..........	C_{co}
Cusp outline complete........	C_{oc}
Crown $\frac{1}{2}$ complete...........	$Cr._{1/2}$
Crown $\frac{3}{4}$ complete...........	$Cr._{3/4}$
Crown complete..............	$Cr._c$
Initial root formation.........	R_i
Initial cleft formation.........	$Cl._i$
Root length $\frac{1}{4}$................	$R_{1/4}$
Root length $\frac{1}{2}$................	$R_{1/2}$
Root length $\frac{3}{4}$................	$R_{3/4}$
Root length complete.........	R_c
Apex $\frac{1}{2}$ closed................	$A_{1/2}$
Apical closure complete.......	A_c

Table I. Specific facts about children in study.

Table II. Eruptive movement (mm) of study and control teeth for 1st and 2nd 3-month intervals and totals for 6-month interval.

SPECIFIC FACTS ABOUT CHILDREN IN STUDY					
No.	Sex	Initial Age	Duration in Study	Tooth Extracted	Study Tooth
1	M	10y. - 9mo.	6 mo.	|E	|5
2	F	9y. - 6mo.	6 mo.	|E	|5
3	F	6y. - 2mo.	6 mo.	D|	4|
4	F	7y. - 4mo.	6 mo.	D|	4|
5	M	7y. - 4mo.	6 mo.	|D	|4
6	M	9y. - 8mo.	6 mo.	D|	4|
7	M	11y. - 8mo.	3 mo.	|E	|5
8	F	8y. -10mo.	3 mo.	|D	|4

TABLE I

ERUPTIVE MOVEMENT (MM) OF STUDY AND CONTROL TEETH FOR 1st AND 2nd 3-MONTH INTERVALS AND TOTALS FOR 6-MONTH INTERVAL											
Patient No.	Study Tooth No.	Control Tooth No.	1st 3-Month Interval			2nd 3-Month Interval			Totals for 6-Month Interval		
			Study Tooth	Control Tooth	Difference	Study Tooth	Control Tooth	Difference	Study Tooth	Control Tooth	Difference
1	|5	5|	3.6	0.7	+2.9	3.5	0.7	+2.8	7.1	1.4	+5.7
2	|5	5|	1.4	1.3	+0.1	1.1	0.7	+0.4	2.5	2.0	+0.5
3	4|	|4	0.6	0.5	+0.1	0.6	0.6	0.0	1.2	1.1	+0.1
4	4|	|4	0.7	0.4	+0.3	1.7	1.7	0.0	2.4	2.1	+0.3
5	|4	4|	1.9	1.0	+0.9	2.1	0.6	+1.5	3.0	1.6	+2.4
6	4|	|4	3.6	1.6	+2.0	2.2	2.2	0.0	5.8	3.8	+2.0
7	|5	5|	1.4	1.0	+0.4						
8	|4	4|	3.4	2.0	+1.4						

TABLE II

Table III. Eruptive movement (mm) of premolars other than study and control teeth for 1st and 2nd 3-month intervals and totals for 6-month interval.

Table IV. Antero-posterior component of eruptive movement of premolars during 6-month interval.

ERUPTIVE MOVEMENT (MM) OF PREMOLARS OTHER THAN STUDY AND CONTROL TEETH FOR 1st AND 2nd 3-MONTH INTERVALS AND TOTALS FOR 6-MONTH INTERVAL				
Pat. No.	Tooth No.	1st 3-Month	2nd 3-Month	6-Month Totals
1	⌈4 4⌉	1.6 4.2	2.6 2.3	4.2 6.4
2	⌈4 4⌉	1.5 1.6	1.1 1.1	2.6 2.7
3	⌈5 5⌉	0.2 0.0	0.4 0.1	0.6 0.1
4	⌈5 5⌉	0.6 0.0	1.6 2.0	2.2 2.0
5	⌈5 5⌉	0.8 0.3	1.2 1.2	2.0 1.5
6	⌈5 5⌉	2.2 1.5	0.9 1.3	3.1 2.8
7	⌈4 4⌉	2.0 1.2		
8	⌈5 5⌉	0.6 1.0		

TABLE III

ANTERO-POSTERIOR COMPONENT OF ERUPTIVE MOVEMENT OF PREMOLARS FOR 6-MONTH INTERVAL (MM)							
Patient No.	Tooth No.	A - P Component	Eruptive Movement	Patient No.	Tooth No.	A - P Component	Eruptive Movement
1	⌈4 ⌈5 4⌉ 5⌉	1.0 1.0 2.0 0.0	4.2 7.1 6.5 1.4	4	⌈4 ⌈5 4⌉ 5⌉	2.0 0.0 2.0 1.0	2.1 2.2 2.4 2.0
2	⌈4 ⌈5 4⌉ 5⌉	2.0 0.0 2.0 2.0	2.6 2.5 2.7 2.0	5	⌈4 ⌈5 4⌉ 5⌉	1.0 0.0 3.0 1.5	1.6 2.0 3.0 1.5
3	⌈4 ⌈5 4⌉ 5⌉	0.0 0.0 0.5 0.0	1.1 0.6 1.2 0.1	6	⌈4 ⌈5 4⌉ 5⌉	0.0 0.0 3.0 0.0	3.8 3.1 5.8 2.8

TABLE IV

Table V. Increase in root length (mm) of study and control teeth for 1st and 2nd 3-month intervals and totals for 6-month interval.

Table VI. Increase in root length (mm) of premolars other than study and control teeth for 1st and 2nd 3-month intervals and totals for 6-month interval.

INCREASE IN ROOT LENGTH (MM) OF STUDY AND CONTROL TEETH FOR 1st AND 2nd 3-MONTH INTERVALS AND TOTALS FOR 6-MONTH INTERVAL											
Patient No.	Study Tooth No.	Control Tooth No.	1st 3-Month Interval			2nd 3-Month Interval			Totals for 6-Month Interval		
			Study Tooth	Control Tooth	Difference	Study Tooth	Control Tooth	Difference	Study Tooth	Control Tooth	Difference
1	⌈5	5⌉	0.8	1.0	-0.2	1.9	0.3	+1.6	2.7	1.3	+1.4
2	⌈5	5⌉	0.9	2.0	-1.1	1.1	0.1	+1.0	2.0	2.1	-0.1
3	4⌉	⌈4	1.1	0.5	+0.6	0.1	0.0	+0.1	1.2	0.5	+0.7
4	4⌉	⌈4	0.8	0.0	+0.8	1.8	1.9	-0.1	2.6	1.9	+0.7
5	⌈4	4⌉	0.9	0.0	+0.9	0.2	0.9	-0.7	1.1	0.9	+0.2
6	4⌉	⌈4	2.2	0.5	+1.7	0.8	0.7	+0.1	3.0	1.2	+1.8
7	⌈5	5⌉	0.6	1.1	-0.5						
8	⌈4	4⌉	0.1	0.5	-0.4						

TABLE V

INCREASE IN ROOT LENGTH (MM) OF PREMOLARS OTHER THAN STUDY AND CONTROL TEETH FOR 1st AND 2nd 3-MONTH INTERVALS AND TOTALS FOR 6-MONTH INTERVAL				
Pat. No.	Tooth No.	1st 3-Month	2nd 3-Month	6-Month Totals
1	⌈4 4⌉	1.8 2.3	0.9 0.7	2.7 3.0
2	⌈4 4⌉	1.2 1.1	1.2 0.8	2.4 1.9
3	⌈5 5⌉	1.5 0.5	0.0 0.5	1.5 1.0
4	⌈5 5⌉	0.3 1.0	0.7 0.8	1.0 1.8
5	⌈5 5⌉	1.0 0.2	0.0 0.8	1.0 1.0
6	⌈5 5⌉	3.1 1.2	0.4 1.4	3.5 2.6
7	⌈4 4⌉	0.7 0.4		
8	⌈5 5⌉	0.7 0.5		

TABLE VI

DISCUSSION

It is not within the scope of this thesis to review all the literature pertinent to the subject of the eruption of teeth. Likewise, it is not feasible to evaluate and discuss the plethora of studies that have been directed toward the many aspects of that subject. It would be difficult to decide where to begin and where to end such a project. While research in this area has been sizable, the basic mechanisms of the process of eruption are still not well understood and much of what is said about the eruption of teeth is theoretical. The review of literature in this thesis, therefore, has been limited to those studies and observations that are pertinent to the scope of its problem.

There is some confusion regarding the terminology found in the literature directed toward the problem of deciduous molar loss and the eruption of succedaneous teeth. The word "eruption" in its various forms has been used without definition. Some authors have used the term to encompass the entire process in which teeth move occlusally through the jaw and into the oral cavity to meet their antagonists and continue to move to maintain proper relation to the jaw and to each other. Others apply the term to that moment when the crown of a tooth makes its appearance through the oral mucosa. Without definition, the conclusion that the eruption of a tooth is accelerated or retarded is ambiguous. The reader is left in doubt as to whether the whole or a portion of the process has been effected or if the clinical appearance of the tooth is earlier or later than expected. Fanning[20] reported instances in which a portion of the eruption process prior to the clinical appearance of a tooth appeared to be accelerated when compared to its antimere and, yet, its date of clinical emergence was later.

The terms "early" and "premature" when used to date the loss of deciduous teeth from the dental arch can be ambiguous, if not defined. The early or premature loss of a deciduous tooth may indicate its loss by trauma or extraction prior to the normal shedding age for an individual. It may also mean the loss for any reason, including normal shedding, at an age prior to the mean shedding age for a population.

In this discussion, the author will use the term "eruption" to refer to the entire process and the terms "clinical emergence" and "clinical appearance" to describe that event. The term "untimely" is used to describe the loss of a deciduous molar due to extraction prior to the anticipated shedding date for an individual.

Previous studies reporting on deciduous molar loss and the eruption of premolars have been with one exception, cross-sectional in nature and have not considered individual variation in the rate of eruption prior to clinical emergence. The incidence of periapical infection associated with the extracted deciduous molars has not been included in these studies nor has the incidence of premolar impaction due to a resultant loss of space in the dental arches. Both of these are factors which have been suggested as effecting the date of clinical emergence of the premolar. While some studies such as Kronfeld[17] and Carr[23] have considered the age at which the extraction occurred as a variable, most others have not. To date, only Fanning[20] has approached this problem with consideration of individual variation in the rate of eruption. Unfortunately, her sample, like that in this study, was not of sufficient size to offer many significant results. Furthermore, her study did not report control of the variables of periapical infection and premolar impaction. Her most meaningful conclusion was that there is individual variation in the effect of deciduous molar extraction on the rate of eruption of the succedaneous tooth.

This study attempted to consider individual variation in the effect of untimely loss of deciduous molars on the rates of development and eruption of the succedaneous premolars in the absence of periapical infection and premolar impaction.

If it is to be assumed that the untimely loss of a deciduous molar can exert some influence on the eruption of its permanent successor, some theoretical consideration should be given to how that influence might be manifested. In light of the fact that the normal mechanism of eruption has not been established, this area of discussion, though interesting, can be little more than speculative.

Leslie[16] has suggested that there may be a relationship between the cellular elements of the deciduous periodontal membrane and the general resorptive processes associated with the phenomena of eruption of the premolar and resorption of the deciduous molar. The loss of the deciduous molar, then, would remove this eruption promoting factor and the result would be a retardation of the rate of eruption of the successor. This influence, he suggests, is only in force prior to the time the crown of the erupting tooth disrupts the deciduous periodontal membrane. This could explain the conclusions of some that loss of a deciduous molar at an early age has the effect of delaying the date of clinical emergence while loss at a later age accelerates it. In terms of this study, it might be noted that only one child (Patient No. 3) exhibited a study tooth that radiographically had not yet disrupted the deciduous periodontal membrane and that tooth showed the least amount of difference in eruptive movement (0.1 millimeter) in six months compared to its antimere. This observation is not significant, of course, but is interesting in consideration of this theory.

Kjellgren[9] has suggested that a retarding effect on the date of clinical emergence of a premolar might be due to a replacement by bone in the spaces previously occupied by the deciduous roots. The assumption is that bone is less readily resorbed in the eruption process than root material. There is no evidence to either substantiate or disprove this assumption. Retained deciduous root tips are not uncommon; on the other hand, unresorbed alveolar bone accompanying the clincial emergence of a tooth has been demonstrated.

It has also been proposed that fibrosis of mucosa over the extraction site can occur and delay the clinical emergence of the premolar. Sleichter[24] observed in a few cases in his study that he followed serially that the study tooth appeared to erupt more rapidly than its antimere until it penetrated the cortical plate of bone at which time the eruption of the two teeth became more symmetrical. Fanning,[20] as mentioned earlier, reported a similar finding. Only one subject (Patient No. 1) in this study had a study tooth emerge. This occurred sometime during the second three-month interval. The difference in the eruptive movement of the study tooth and its antimere remained almost constant for both three-month intervals. This finding does not necessarily refute this theory. If this theory is valid, it does suggest that, at least in this case, three months after extraction was not a sufficient interval for the fibrosis to exert a discernible influence.

The suggestion has been made that the fibrosis of alveolar mucosa following the extraction of a deciduous molar can be minimized by placing a prosthesis with an acrylic saddle over the area. The author feels that this consideration is worthy of investigation. He further feels that for this reason and others, also worthy of investigation, the partial denture type of space maintainer may have enough merit to indicate its use over the non-functional types.

Leslie[16] has also proposed that the removal of a deciduous tooth might modify the functional stresses, normally transmitted to the underlying tissue. The reduction in function, he theorizes, would then have the effect of reducing the resorption process in the area of the succedaneous tooth and, as a result, retard its eruption. This hypothesis bears investigation as another consideration in the use of the functional space maintainer. While the results of this study suggest that loss of deciduous molar function does not initially retard the rate of eruption of the succedaneous tooth, it does not conclude the loss of function is without any effect. The author proposes a future long-term, serial investigation, similar in method to this study, in which the rate of eruption of the premolar following extraction of the deciduous molar is measured and compared in two groups of children. One group would be provided with non-functional space maintainers and the second, with the functional type.

Leslie[16] has further suggested that the acceleration of the clinical emergence of the succedaneous tooth, when extraction has occurred at an age near the normal shedding age, (as in Patient No. 1), can be due to the removal of alveolar bone in the bifurcation area of the deciduous molar during the extraction procedure thus removing a barrier to the erupting tooth. It would be assumed that if this theory and the hypothesis of fibrosis of the mucosa are both valid, emergence in this situation would have to occur before the mucosa became sufficiently fibrotic to impede eruption.

Little consideration will be given to the effect of periapical infection following pulpal necrosis in a deciduous molar on the eruption of the succedaneous tooth, not to suggest that the effect is clinically unimportant, but because infection was not a variable in this study. Clinical observations by the author have substantiated for him reports that premolars can erupt much earlier than anticipated when there has been periapical infection present. However, in observing the eruption of a premolar whose predecessor has been periapically infected and ultimately extracted, it must be remembered that both the infection and extraction could be separate factors of influence on the eruption of the premolar. The effect of periapical infection alone on the eruption of premolars is a problem worthy of future investigation.

Impaction of the erupting premolar due to the drifting or tipping of adjacent teeth into the space previously occupied by the extracted deciduous molar was another variable that was eliminated in this study. The closure of space, like periapical infection, is another variable that must be considered separately from the extraction as an influence.

While previous studies[2-7] have shown that space closure and resultant premolar impaction does occur, it has not been demonstrated that the movement of adjacent teeth have an effect on the rate of eruption prior to the moment when impaction occurs (i.e. when the eruptive movement of the premolar ceases). Information resulting from a study of this problem might be of value when procedures to regain lost space are anticipated.

In considering the various hypothesis in regard to the effect of untimely loss of deciduous molars on the eruption of the the succedaneous premolars, it becomes apparent that the factor of age may be of some importance. It is not only a question of the occurrence of certain conditions (e.g. mucosal fibrosis, loss of alveolar bone, etc.) and the resultant effect, but also, a question of when the condition occurs. This study was limited to children in the mixed dentition. Leslie,[16] Kronfeld[17] and Carr[23] have considered age difference in their reports but have offered no more specific information than that age appears to be a variable. This is due to the type of study employed, a cross-sectional method, in which other variables were not considered.

Perhaps a solution to this problem of understanding the role of the many variables associated with the untimely loss of deciduous molars on the eruption of the succedaneous premolars would be the use of a sophisticated, multivariant statistical analysis of data from a long-term, serial study of a large group of children. The possibility or practicality of the statistical aspects of such a study are not, at present, within the author's realm of knowledge.

The value of this study in regard to its clinical applications is limited for two reasons. The duration of observation, three and six months, for the children serially studied provided only initial determinations. The fact that extraction of a deciduous molar apparently accelerated the rate of eruption of the succedaneous premolar in some cases during the first three or six months does not mean that the effect will continue to be accelerative. The clinician is ultimately interested in predicting the time of one phase of the premolar eruption process, the clinical emergence. What significant results can be gleaned from this study are of value only in the theoretical or speculative sense. Secondly, the size of the sample studied did not provide many results which could be tested for statistical significance with any degree of confidence.

There is not, at present, a method to serially study the process of eruption, i.e. the movement of the developing tooth within the jaw, other than the employment of the radiograph. There is a certain amount of error of enlargement and distortion between the radiographic image and the actual structure inherent in any radiographic technique. The magnitude of this error is critical in studies employing linear measurements. Moreover, in a serial study where a difference in linear distance between two reference points on successive films is used as a measure of change, it is necessary this error be standardized for successive radiographs.

This study employed a oriented radiographic technique that provided an acceptable magnitude of error that could be standardized for successive radiographs. Barber, Pruzansky and Kindelsperger[26] tested the reliability of measurements obtained from the 45 degree film by comparing measurements between metallic reference discs cemented on dry skulls with those obtained from 45 degree projections of the skulls. They found that the magnitude of error found in the buccal segments of jaws was no greater than that found in the accepted lateral cephalometric projections. This technique further provides an image of the buccal segment of one side of the jaw that is free from superimposition by contralateral structures. There has not been, at present, a report of any study directed to the problem with which this thesis is concerned that has employed a cephalometric radiographic technique.

While the 45 degree cephalometric radiograph was found to be applicable to this study, it was not without certain shortcomings. The author originally intended to include determinations of the permanent cuspids in this study. It was found, however, in a number of films, specifically those of the older children, the image of the erupting permanent cuspid was not completely discernible due to superimposition of the image of the mandibular ramus of the opposite side.

Another problem encountered was the lack of established, stable landmarks to serve as reference points for measurements. A superpositioning technique was used in measuring the eruptive movement of premolars on successive films. The bony anatomy of the inferior border of the mandible beneath the area of the premolars was selected since this area of the mandible is thought to have a minimum amount of change with normal growth. The author found that he could superposition initial tracings on successive films using this area of reference with a high degree of confidence in the accuracy of coincidence. It is not known if this area of reference would remain sufficiently stable for use in serial studies of a longer duration. It was noted that composite tracings with this technique demonstrated the greatest amount of change in the anatomy of the mandible to occur in the expected areas of growth or resorption, such as the posterior and anterior borders of the ramus (Figure 3). The author suggests that research directed toward this problem and toward the establishment of reliable, stable landmarks for this technique would be valuable for future studies employing the 45 degree cephalometric radiograph.

Eruptive movement of teeth was determined in this study by measuring this distance between cusp-tips, marked with pinholes, on an initial tracing and successive films.

Both Fanning,[20] in a serial study and Scleichter[24] in a cross-sectional study employed intraoral radiographs for their determinations. They used a similar measurement to ascertain the position of the erupting premolar to its surroundings. Their measurement was made between the cusp-tip and the crest of the alveolar bone above the erupting tooth. The measurement of the study tooth, whose predecessor had been extracted, was compared to its antimere to assess the difference in the distance to the alveolar crest which served as a base line. The author feels that there are two errors inherent in this method. To serve as a base line for measurements in a serial study, the alveolar crest should be an area of relatively little growth. There is evidence that it is not. Secondly, there is the possibility of surgical reduction in the height of the alveolar crest at the time of the extraction. This loss would not provide a comparable situation with the alveolar crest of the opposite side to justify its use as a control. The latter error might explain the initial "spurt" of two to three millimeters in the rate of eruption of the study tooth in the first six months that Fanning[20] consistently found. In this study, an initial "spurt" in eruptive movement was not observed in every patient. Three children showed differences between the study teeth and control teeth of 2.0 to 5.7 millimeters during six months. In three others the difference was from 0.1 to 0.5 millimeters. Three patients showed no difference in the rate of eruption during the second three-month interval.

A consideration of the eruptive movement of all premolars included in this study indicate that there is variation in the rate of eruption of premolars for a population and for an individual. There is also variation in the rate of eruption for an individual premolar between given intervals.

The eruptive movement of some premolars in this study exhibited movement in a antero-posterior direction as well as occlusally. The method of assessing this lateral component of movement requires explanation. A composite tracing was used on which a base line was constructed between two anatomical points on the inferior border of the mandible (Figure 2). A point was selected on the tracing as a mean of the corresponding points on each film since there was not perfect coincidence of the points in every case.

This part of the procedure introduced an element of error. The reference grid was oriented along the base line with one vertical coordinate passing through the cusp-tip of the initial premolar on the composite tracing. Measurements were made from that vertical coordinate to successive cusp-tips along the horizontal coordinate nearest each successive cusp-tip. This part of the procedure also introduced an element of error. Therefore, the findings in this determination should not be considered as an accurate assessment of the amount of antero-posterior eruptive movement nor should the determination for any premolar be considered as a true function of its total eruptive movement. This assessment was made only to illustrate the direction of eruptive movement. This method was found to be insufficiently sensitive to make determinations with any degree of confidence when the total eruptive movement was less than 1.0 millimeters. Therefore, only determinations for a six month interval were considered. In all cases where this component occurred, it was posterior.

Neither the reason nor significance of this occasional apparent posterior movement is understood.

So far, this discussion has only dealt with the effect of untimely deciduous molar loss on the eruption of the succedaneous tooth. This study was also concerned with the effect on the development of the premolar. Only Fanning[20] has reported on this problem. She assessed the development of the premolars in her study by comparing radiographic images of the teeth to a prepared illustration depicting arbitrary stages of development of single rooted teeth, identical to the one employed in this study (Figure 4). She found in her sample of eight children that the extraction of a deciduous molar had no effect on the rate of development of the succedaneous premolar. This method of assessment was found to be insufficiently sensitive to be of value in this short-term study. Therefore, no meaningful comparison can be made between her findings and the findings of this study on the basis of this method. This study also assessed tooth development in terms of measurement of root growth. An evaluation of the illustration (Figure 4.) will show that the difference between the stages of formation from Cr_c (Crown complete) to R_c (Root complete) are actually based on root growth. Therefore, the linear measurement of root growth is only a more sensitive method using the same criterion for expressing tooth formation. This study found no relationship between the loss of the deciduous molar and the rate at which the succedaneous tooth develops in the first six months.

The method of linear measurement did provide the opportunity of comparing the amount of eruptive movement to the amount of root growth for a single tooth during a given interval. No constant relationship was found for the individual tooth, either study tooth or any of the other premolars. In some cases, the tooth erupted a greater distance than the root increased; in other cases, the root increased more than the tooth moved. This finding added corroboration to the existing concept that eruption of a tooth is not solely dependent on root growth. There was, however, a moderate correlation found between the increase in root length and the amount of eruptive movement for all premolars. This is not surprising since both of these phenomena occur simultaneously without regression. This correlation suggests that from the standpoint of clinical meaningfulness, there is merit to predicting the time of clinical emergence of an individual tooth from a radiographic assessment of its stage of formation.

SUMMARY AND CONCLUSIONS

This study was undertaken by the author when it was realized that there is a lack of knowledge of the individual variations in the effect of the untimely loss of deciduous molars on the eruption and development of the succedaneous premolars. Eight children, patients of the Pedodontic Clinic of the Indiana University School of Dentistry, who were in the mixed dentition stage of dental development, participated in a serial radiographic study which utilized 45 degree cephalometric films made at three-month intervals. At the onset of the study, each child had one mandibular deciduous molar extracted for a justifiable reason other than periapical involvement and a soldered lingual arch space maintainer provided. All determinations were made from measurements and observations from a 45 degree cephalometric film series consisting of left and right films taken at the onset of the study, at three months and again, at six months for six of the subjects. The amount of eruptive movement of each premolar was determined by measurement of the linear distance between the cusp tip on a superpositioned tracing of the initial film and the corresponding cusp tip on the successive films. The antero-posterior component of eruptive movement was evaluated on a composite tracing by measurement between corresponding cusp tips along grid lines oriented to a common base line. Tooth formation was assessed by measuring the increase in root length for each premolar on successive films and by comparing the apparent stage of development of each premolar image to a prepared illustration depicting arbitrary stages of premolar development.

For each determination the premolar whose predecessor was extracted was designated as the study tooth and its antimere as the control tooth. Each determination was also made for the other two premolars.

The clinical value of the results obtained in this study is limited for two reasons. The size of the sample studied is not sufficiently large for most of the findings to have statistical significance. The duration of the study was not long enough to relate the initial findings to the long-term or over-all effects. However, the methods employed in this study may be found to have value in a longer and more comprehensive study.

Variation in the rate of eruption of mandibular premolars was found within the sample for the individual and for the individual tooth. The mean amount of eruptive movement for a three-month interval for all premolars other than the study teeth was found to be 1.19 millimeters. The mean amount of eruptive movement for the study teeth for a three-month interval was 1.98 millimeters. A comparison of these means revealed some significance ($0.001 < P < 0.01$). In no instance did a control tooth exhibit greater eruptive movement in a given interval than a study tooth. The initial effect of the untimely loss of a deciduous molar on the rate of eruption of the succedaneous premolar in this study appears to be accelerative.

The eruptive movement of premolars occasionally demonstrated a posterior component. This posterior movement occurred more often with first premolars. The untimely loss of a deciduous molar did not appear to have an effect on this phenomenon.

The increase in root length during a given time interval for mandibular premolars varied within the sample, for the individual and for the individual tooth. The mean increase in root length for all premolars for a three-month period was 0.83 millimeters.

The untimely loss of the deciduous predecessor appeared to have no effect on the rate of root growth of the premolar.

While there was a moderate correlation between increase in root length and amount of eruptive movement for all premolars in this study ($r = 0.66$), eruptive movement did not appear to be dependent on root growth nor was root growth dependent on eruptive movement for an individual tooth during a given interval. A total of 56 comparisons was made. In 39 instances the eruptive movement in the three-month interval was greater than the concurrent root growth. In 16 instances the root growth was greater than the eruptive movement. In one case the amount of root growth and eruptive movement was the same.

The method of serially evaluating tooth development by comparing radiographic images to a prepared illustration depicting arbitrary stages of development was judged to be insufficiently sensitive to be of value in a short-term study.

More comprehensive studies of longer duration would offer information with more clinical significance than that accrued from the present study. It is suggested that future studies should include investigation of such variables as age, the presence and absence of periapical infection and the type of space maintenance provided (functional or non-functional).

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ABSTRACT

The effect of untimely loss of deciduous molars on the eruption and development of succedaneous premolars was serially studied in eight children in the mixed dentition stage from 45 degree cephalometric films made at three and six month intervals. Each child had one mandibular deciduous molar removed for reasons other than periapical infection and a lingual arch space maintainer provided. The premolar beneath the extracted molar served as the study tooth; its antimere, as the control tooth.

Eruptive movement was measured as the distance between the cusp-tip of a premolar on a superpositioned initial tracing and the corresponding cusp-tip on successive films. Antero-posterior movement of premolars was evaluated on a composite tracing along grid lines oriented to a common base line. Tooth formation was assessed by the increase in root length on successive films.

Variation was found in the amounts of eruptive movement and root growth during a three month interval, for all premolars within the sample, within an individual and for a single tooth. In no case did a control tooth erupt more than a study tooth in a given interval. The initial effect of deciduous molar loss on eruptive movement in this study appeared to be accelerative. Tooth development was not found to be effected. While moderate correlation was found between eruptive movement and root growth for all premolars, one process did not appear to be solely dependent on the other. A posterior component of eruptive movement was occasionally demonstrated but was not related to the extraction. The clinical value of this study is limited due to its small sample and short duration. Longer and more comprehensive studies of this problem are recommended.